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(54) ILLUMINATING DEVICE AND DISPLAY USING THE DEVICE

BELEUCHTUNGSVORRICHTUNG UND ANZEIGE WELCHE DIESE VERWENDET

ILLUMINANT ET PANNEAU AFFICHEUR L'UTILISANT

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(73) Proprietor: SEIKO EPSON CORPORATION
Tokyo 163 (JP)

(72) Inventors:
- FUNAMOTO, Tatsuaki
Suwa-shi, Nagano-ken 392 (JP)
- YOKOYAMA, Osamu
Suwa-shi, Nagano-ken 392 (JP)
- MIYASHITA, Satoru
Suwa-shi, Nagano-ken 392 (JP)
- KUBOTA, Kanemitsu
Suwa-shi, Nagano-ken 392 (JP)

(74) Representative: Kenyon, Sarah Elizabeth et al
Miller Sturt Kenyon
9 John Street
London WC1N 2ES (GB)

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Description

1. Field of the Invention

[0001] The present invention relates to an illumination device and display device using this wherein a light-guide plate is arranged at the front face of an illuminated object and this illuminated object is two-dimensionally surface-illuminated, and more particularly relates to an illumination device and display device using this wherein properties such as illumination function, recognisability, contrast and energy-saving that are based on the optical diffusion characteristic of this light-guide plate are greatly improved.

2. Description of the Related Art

[0002] Conventionally, various types of illumination device are employed that exhibit the function of surface illumination in respect of a display device that requires planar illumination, such as a liquid crystal display device.

[0003] For example there is known a display device that is arranged at the back face of the object to be illuminated, such as a liquid crystal display panel; normally such an illumination device is arranged to be constantly lit. An illumination device is also known mounted on a liquid crystal display device having a reflective function. In the case of such an illumination device, a reflective plate is arranged at the back face of the liquid crystal display panel and the device is employed by illumination provided by external light. Furthermore, an illumination device is also known that is arranged together with a semi-transparent reflective plate at the back face of a liquid crystal display panel; this illumination device is used for reflection when the environment is brighter and to provide back lighting illumination when the environment is dark (for such devices for example Early Japanese Patent Publication JP-A-049271/82, Early Japanese Patent Publication (JP-A-054926/82), and Early Japanese Patent Publication JP-A-095780/83 may be referred to).

[0004] However, conventional illumination devices having solely an illumination function suffered from the problem that power consumption in order to keep the light source constantly lit was large; for example, they could not be used over a long time to provide illumination for portable equipment. Also, in the case where a conventional display device having solely a reflective function was mounted on a liquid crystal display device or the like, there was the problem that contrast of the display screen was low, making it impossible to employ them in a dark environment. Furthermore, illumination devices that are employed with a semi-transparent reflective plate inevitably have the problem that the display is dark both when used with reflection and when used with back lit illumination; this technique represents an unsatisfactory compromise and has not become popular at all.

[0005] In these circumstances there has recently been proposed for example in Early Japanese Patent Publication JP-A-6-324331 an illumination device that is arranged at the front face of a display device such as a liquid crystal display device. The illumination device of this proposal is incorporated in a thin liquid crystal display device and has the object of ensuring high contrast of illumination both when lit and when not lit. Specifically, a thin illumination device is arranged at the top face (front face) of a liquid crystal display and a reflective plate is arranged at the back face of the liquid crystal display. The illumination device comprises a light-guide plate and a light source that is arranged at the end face of this light-guide plate or in its vicinity. At the optical output face of the light-guide plate, there is formed an indented shape comprising faces practically parallel with this face and faces approximately perpendicular thereto. The indented shape may be formed for example of a plurality of ribs or projections of cylindrical or prismatic shape.

[0006] However, the illumination devices arranged at the front face of these publications are adapted to light sources of rod or linear shape. For such light sources, fluorescent tubes, which are of high light-emitting efficiency are generally employed; however, fluorescent tubes need power of at least a certain level and suffer from the problem that their power consumption cannot be reduced below this. Also, if point light sources such as LEDs or electric light bulbs were employed, there was the problem that, since the lines of intersection at the root sections forming the ribs or prismatic projections and optical output faces are straight lines, the quality of illumination tends to be adversely affected by regular reflection. Furthermore, in the case of point light sources, there was the problem that unevenness of brightness could not be eliminated by one-dimensional distribution control of the pattern of the projections. Also, illumination devices arranged at the front face in this way were subject to the problem of being easily affected by external damage to the light-guide plate, causing light to be emitted by dispersive reflection of optical flux from such damaged portions, lowering the contrast of the illuminated object such as the liquid crystal display when lit: Also, with such illumination devices of the type that were arranged at the front face, since the light source is arranged at the end face of the light-guide plate, a space needs to be provided at the end of the light-guide plate sufficient to screen the light source from the observer; if they are employed as illumination for a liquid crystal display or the like, a border is therefore necessary around the periphery of the display area. This resulted in waste of space and imposed considerable design limitations.

[0007] JP-U-145902/86 discloses an illumination device comprising a light guide plate, formed of a transparent flat plate with optical extraction structures, and a point light source arranged facing an end face of the light

guide plate.

[0008] In one aspect, the present invention was made in order to solve the various problems of a conventional illumination device as described above.

[0009] An object of the present invention is to provide an illumination device using a point light source of low power consumption and high quality, and a display device such as a liquid crystal display device using this. Also, a further object of the present invention is to provide an illumination device of low power consumption and high quality by employing as light source a light emitting diode (LED), and a display device such as a liquid crystal display device using this. Yet a further object of the present invention is to provide an illumination device whereby illumination can be achieved without loss of reflective function and a display device such as a notice board device or liquid crystal display device using this, and a device such as an electronic device or mobile.telephone using this liquid crystal display device.

[0010] Yet a further object of the present invention is to provide an illumination device with little deterioration of illumination function by low-cost, convenient means, and a display device such as a liquid crystal display device with little deterioration of display quality.

[0011] Yet a further object of the present invention is to provide an illumination device whereby rays of light can be efficiently directed into the interior of a light-guide plate from a light source positioned remote from the light-guide plate end, which is space-saving, and has excellent design characteristics, a display device such as a liquid crystal display device, and a device such as an electronic device or mobile telephone using this liquid crystal display device.

[0012] Furthermore, from the point of view of display devices in which an illumination device is mounted, in view of conventional reflective type liquid crystal display devices for the aforesaid display devices, it is an object to provide various types of electronic device such as liquid crystal display devices, portable telephone devices, timepieces, cameras or data terminal devices wherein the production of a bright line which is annoying to the observer can be prevented, wherein unevenness of brightness can be eliminated, which are of a type in which power consumption can be reduced and furthermore which afford an illumination function of high quality.

[0013] Furthermore, conventionally, notice board devices having an illumination function were of a construction in which a casing was provided whose front face was covered by transparent glass and wherein a notice was illuminated by arranging a light source at the front edge of the notice. Also, they were of a construction in which the person viewing them could not directly see the light source due to an optical screening section, also serving as a casing, in front of the light source.

[0014] However, conventional notice board devices suffered from the problem that they had to be of sufficient thickness in order for the entire notice to be illuminated, and that the difference of illumination was large at locations remote from the vicinity of the light source.

[0015] Also, in a further aspect relating to a display device, an object of the present invention is to provide a notice board device wherein such problems are solved and which is of small thickness and wherein the uniformity of illuminance is high.

SUMMARY OF THE INVENTION

[0016] In order to solve the aforementioned problems, in one aspect thereof, the present invention provides an illumination device arranged at the front face of an illuminated object, comprising:

> a light-guide plate of transparent flat plate shape formed with point-form optical extraction structures; and
>
> a light source arranged facing an end face of this light-guide plate, said light source being a point light source (Illumination device of the type disclosed in JP-U-145902/86), characterised in that:
>
> > said point-form optical extraction structures are formed at the face opposite an optical output face facing said illuminated object; and
> >
> > said point-form optical extraction structures have a constant slope of less than about 30 degrees with respect to said face opposite the optical output face.

[0017] Features relating to further structure and benefits of the present invention will be apparent from the detailed description of the accompanying drawings and the following embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

> Fig. 1A and Fig. 1B are a diagrammatic cross-sectional view and perspective view illustrating a first example, not forming part of the present invention;
>
> Fig. 2A and Fig. 2B are diagrams illustrating a problem of the prior art;
>
> Fig. 3 is a diagrammatic cross-sectional view of a modification of the first example;
>
> Fig. 4 is a diagrammatic cross-sectional view of a further modification of the first example;
>
> Fig. 5 is a diagrammatic cross-sectional view of a further modification of the first example;
>
> Fig. 6 is a diagrammatic cross-sectional view of a further modification of the first example;
>
> Fig. 7 is a diagrammatic cross-sectional view of a further modification of the first example;
>
> Fig. 8 is a plan view showing a second example, not forming part of the present invention;
>
> Fig. 9A and Fig. 9B are diagrammatic cross-sec-

tional views of a modification of the second example;

Fig. 10 is a diagrammatic cross-sectional view showing a third example, not forming part of the present invention;

Fig. 11 is a diagram showing a further modification;

Fig. 12A and Fig. 12B are diagrammatic plan views showing a further modification;

Fig. 13 is a diagram showing yet a further modification;

Fig. 14A and Fig. 14B are a diagrammatic cross-sectional view and perspective view showing a first embodiment of the present invention;

Fig. 15 is a detail diagram of a convex shape constituting a structural element for extraction of light;

Fig. 16A to 16D are diagrams of further convex shapes;

Fig. 17 is a diagram of a further convex shape;

Fig. 18 is a diagrammatic plan view of a further modification of the first embodiment;

Fig. 19 is a diagrammatic cross-sectional view of a further modification of the first embodiment;

Fig. 20 is a diagrammatic cross-sectional view of a further modification of the first embodiment;

Fig. 21 is a diagrammatic cross-sectional view of a further modification of the first embodiment;

Fig. 22 is a diagrammatic cross-sectional view of a further modification of the first embodiment;

Fig. 23A and Fig. 23B are a diagrammatic cross-sectional view and perspective view of a second embodiment of the present invention;

Fig. 24 is a detail diagram of a concave shape constituting a structural element for an extraction of light;

Fig. 25A to 25D are diagrams of a further concave shape;

Fig. 26 is a diagram of a further concave shape;

Fig. 27 is a diagrammatic cross-sectional view showing a third embodiment of the present invention;

Fig. 28 is a diagrammatic perspective view of a device illustrating an example of application;

Fig. 29A to Fig. 29C are a perspective view, plan view and side view of an illumination device of a handy type employing the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] Embodiments of the present invention and modifications thereof are described below with reference to the drawings.

(First example, not forming part of the present invention)

[0020] A first example, not forming part of the present invention is described with reference to the drawings. In Fig. 1A one or a plurality of point light sources 2 are arranged at the end face of light-guide plate 11. As shown in Fig. 1B, light-guide plate 11 is provided with projections 12 on one face of the transparent plate; the faces of projections 12 are in all cases constituted by faces practically parallel to optical output face 13 (bottom face 14) and faces practically perpendicular thereto (side faces 15). Light-guide plate 11 is formed by transparent material of refractive index about 1.4 or more. After the optical flux from a point light source 2 is input from end face 16 as shown by ray 19a or ray 19b, it is subjected to total reflection within light-guide plate 11 and is emitted solely from the side faces 15 of projections 12, so the optical output from the back face of the illumination device is large, enabling illuminated element 6 to be efficiently illuminated.

[0021] Also, for the transparent material forming light-guide plate 11, there may be employed transparent resin such as acrylic resin, polycarbonate resin, or amorphous polyolefin resin etc. or inorganic transparent material such as glass or a combination of these; these may be formed by a method such as joining a film or resin layer on to an injection moulding, thermosetting resin, photosetting resin, etching, transparent resin or flat glass sheet.

[0022] As light sources 2, light emitting diodes (LEDs) or electric light bulbs etc. may be employed. In comparison with the fluorescent tubes that were conventionally employed, these do not require special equipment such as voltage step-up devices and are of light weight and compact and excellent safety since they do not employ high frequencies or high voltages. Also, power control is easy and they can easily cope with applications requiring low power consumption. In particular the life of LEDs is semi-permanent and, regarding colours, they have recently become available with red, green, blue, mixtures of these and white colour. If electric light bulbs are employed, although their life is short, they are cheap and can easily be changed.

[0023] With the above construction, by arranging this illumination device at the front face of illuminated body 6, part-time illumination can be achieved in which the illuminated body 6 is observed by turning off illumination under bright conditions when there is sufficient external light, whereas the illuminated body can be observed by switching on illumination under dark conditions when external light is insufficient.

[0024] As the illuminated body 6 of an illumination device as described above, printed material such as printed paper or a liquid crystal display or the like are suitable.

[0025] However, as shown in Fig. 2A, it is found that the lines of intersection of the optical output face 13 of light-guide plate 11 and side faces 15 of projections 12 have a minute curved face in manufacture, so some reflected light 19c leaks towards the face 17 opposite the optical output face (the observer's side) and this can be observed by the observer as bright points. As shown in Fig. 2B, when projections 12 are in the form of ribs and

these intersection lines are straight lines, the point light source 2, the aforesaid bright points, and the observer are located in the same plane, with the result that specific positions on the light-guide plate appear as bright points to the observer and these bright points move with movement of the observer's eye. These adversely affect recognisability of illuminated body 6. In contrast, with the for example cylindrical shape of projections 12 as in this example, since the bright points do not move in the plane of the light-guide plate 11, uniform recognisability can be obtained irrespective of the observation position of the observer.

[0026] Regarding the size of projections 12, since the wavelength of visible light is about 380 nm to 700 nm, this should be at least about 5 μm in order to avoid diffraction effects and in order to make the size of projections 12 such as not to be noticed with the naked eye should be less than about 300 μm. Apart from the above, from the point of view of convenience in manufacture, the size of the projections is desirably above about 10 μm and below 100 μm. Regarding the ratio of the height and width (i.e. the diameter in the case where these are approximately cylindrical) of projections 12, this may be below 1 : 1 since the angle of elevation of a light ray within light-guide plate 11 in the planar direction is less than 45°; and in fact satisfactory performance is exhibited up to a ratio of about 1 : 2, since rays of under 20° represent more than 90%.

[0027] A modification is shown in Fig. 3. In Fig. 3, a concave shape 12a is provided on the side of the face 17 opposite the optical output face of light-guide plate 11. Concave shape 12a can have arbitrary size and shape; it has the function of converting optical flux that reaches this concave shape 12a into optical flux having a large angle of elevation with respect to light-guide plate 11; it is found that a satisfactory characteristic is obtained by making this approximately a spherical surface of central angle under 90°. Optical flux that is fed from point light source 2 into light-guide plate 11 is guided within light-guide plate 11 by repeated total reflection but, thanks to the provision of concave shapes 12a in the face 17 opposite the optical output face of light-guide plate 11, optical flux arriving at these is converted to optical flux having a large angle of inclination with respect to the plane of light-guide plate 11, and can thus be output from optical output face 13. By arranging illuminated body 6 on the side of optical output face 13 of light-guide plate 11, this construction functions as planar illumination. And since regions of the surface other than the concave shapes on the side of face 17 opposite the optical output face are parallel with output face 13, these also have the function of vertical ray transparency i.e. of transmitting rays in the direction that intersects the flat plate at right angles.

[0028] These concave shapes 12a can be provided in any desired area ratio. However, although the efficiency of illumination can be raised by making the area ratio of concave shapes 12a large, recognisability is lowered by decreasing the ratio of perpendicularly transmitted rays. In fact to set an area ratio exceeding 50% is not realistic and as part-time illumination under dark conditions an area ratio of about 10% may suitably be set. Also, if it is desired to increase/decrease their density in order to achieve uniformity of illumination brightness as described above, at about 10%, the area ratio of the perpendicular transmission section is a range of about 80 ~ 90%, so there is no sensation of unevenness of recognisability at different positions. Regarding the size of concave shapes 12a, since the wavelength of visible light is about 380 nm to 700 nm, it is necessary that this size should be at least about 5 μm in order that diffraction effects are not produced and should desirably be less than about 300 μm in order to be such that concave shapes 12a are not noticeable to the naked eye. In addition to the above, from the point of view of convenience in manufacture, the size of the concave shapes should desirably be above about 10 μm and below 100 μm.

[0029] A further modification is shown in Fig. 4. In Fig. 4, concave shapes 12b are provided on face 17 of light-guide plate 11 opposite the optical output face. Convex shapes 12b can have arbitrary size and shape and have the function of converting optical flux arriving at these convex shapes 12b into optical flux having a large angle of elevation with respect to the plane of light-guide plate 11; it is found that good results are obtained by making them approximately conical surfaces of apex angle less than 120°. The density and size of convex shapes 12b are the same as in the case of the concave shapes described above.

[0030] A further modification is shown in Fig. 5. In Fig. 5, an optical diffusion member layer 12c is provided on the side of face 17 opposite to the optical output face of light-guide plate 11. Optical diffusion member layer 12c has arbitrary size and shape and has the function of converting optical flux arriving at this optical diffusion member layer 12c into optical flux having a large angle of elevation with respect to the plane of light-guide plate 11. Specifically, this optical diffusion member layer 12c has the function of optical diffusion towards optical output face 13 and optical screening to face 17 opposite the optical output face. In order to guarantee optical screening, a further optical screening layer can be provided. The density and size of optical diffusion member layer 12c are the same as in the case of the concave shapes described above.

[0031] A further modification is shown in Fig. 6. Fig. 6 shows an example in which point-shaped optical extraction shapes 12x as described above (optical extraction structures) are distributed sparsely in the vicinity of point light sources 2 and more densely further away from point light sources 2. The optical flux density in light-guide plate 11 is high in the vicinity of point light sources 2 but the light rays are diffused by optical extraction shapes 12x and, since the density of the optical flux decreases with increasing distance from point light sources 2, optical extraction shapes 12x are arranged more

densely in continuous manner. More uniform illumination can thereby be achieved.

[0032] A further modification is shown in Fig. 7. In Fig. 7, a transparent plate or transparent sheet 8 is arranged on the side of face 17 opposite the optical output face of light-guide plate 11. Light-guide plate 11 and the transparent plate or transparent sheet 8 are not stuck together and an air layer is present. If there is even slight damage to the surface of light-guide plate 11, the light rays that are guided through its interior are reflected thereat and it can be recognised from the surface as a bright point or bright line. Not only is such damage unattractive in transparent type illumination but it also severely lowers recognisability in that it lowers contrast etc. However, since the transparent plate or transparent sheet 8 is separated from light-guide plate 11 by an air layer, there is no possibility of optical flux entering it from a light source 2, so that even if it does get damaged bright points or bright lines cannot be produced. Also in this case, since the relative area of the damage is very slight, there is very little effect on recognisability of illuminated body 6. In order for this light-guide plate 11 to be used as illumination positioned at the front, the presence of this transparent plate or transparent sheet 8 is indispensable. As the transparent plate or transparent sheet 8, transparent resin such as acrylic resin, polycarbonate resin, or amorphous polyolefin resin, or inorganic transparent material such as glass can be used. Also, in an electronic device incorporating this illumination device, transparent plate or transparent sheet 8 may also serve as the cover glass of the casing.

(Second example, also not forming part of the present invention)

[0033] A second example, not forming part of the present invention is described with reference to the drawings. In Fig. 8, a rod-shaped optical diffuser 18 is arranged at at least one end face of light-guide plate 11 and furthermore a point light source 2 is arranged at an end face orthogonal to the axial direction of rod-shaped diffuser 18. Rod-shaped diffuser 18 has the function of guiding the optical flux of point light source 2 arranged at its end face so that the optical flux is uniformly dispersed from the surface of rod-shaped diffuser 18 by means of diffusing material incorporated in its interior and/or optical diffusion shapes arranged at its surface, thereby providing the function of converting the point light source to a linear light source. Light that is input from the surface of rod-shaped diffuser 18 is led to the end face 16 of light-guide plate 11 and is guided within light-guide plate 11. The optical extraction structures described above are formed at the surface of light-guide plate 11, but, even if the optical diffusion shapes are conventional rib shapes or prism shapes, bright lines at specific positions such as would be produced if a point light source were directly incident cannot appear. For rod-shaped optical diffuser 18, a diffuser incorporating transparent bodies 22a having a refractive index different from that of the transparent resin as in Fig. 9A, or a diffuser formed with an optical diffusion pattern 22b by printing or the like on to the surface of the transparent resin as in Fig. 9B could be employed.

(Third example, also not forming part of the present invention)

[0034] A third example, not forming part of the present invention is described with reference to the drawings. Fig. 10 shows an example in which a liquid crystal display panel is employed as the illuminated body. Light-guide plate 11 is arranged at the front face of liquid crystal display panel 102. A reflecting plate 103 is arranged at the back face of liquid crystal display panel 102, so as to constitute a reflective type liquid crystal display device. Light-guide plate 11 has the function of projecting light rays towards liquid crystal display panel 102 and of transmitting light rays reflected by reflecting plate 103 with scarcely any dispersion. This is particularly effective when light source 2 is extinguished when the external light is sufficient; in this case, light-guide plate 11 acts simply as a transparent plate without lowering the recognisability and so has no effect on display quality. And when this is lit for use in dark locations where there is insufficient external light, light-guide plate 11 illuminates liquid crystal display panel 102 and the reflected light produced by reflecting plate 103 passes directly through light-guide plate 11 which now functions simply as a transparent plate in the same way as in the extinguished case described above. This is therefore effective in maintaining high recognisability.

[0035] Also, whereas, with a transparent-type liquid crystal display device in which the illumination device is arranged at the back face of the liquid crystal panel, bright/dark contrast is generated by passage of the rays from the illumination device through the liquid crystal display panel once only, with a reflective type liquid crystal display device wherein, as in the present example, the display device is arranged at the front face of the liquid crystal display panel, rays from the illumination device pass through one more time since they are reflected by the reflecting plate after once passing through the liquid crystal display panel; this is beneficial in obtaining higher recognisability, since contrast is increased. As described above, with the first to third examples and the modifications thereof, thin surface illumination can be provided suitable for notices or displays.etc. that make use of external light.

[0036] Also, in applications such as portable computer terminals, a liquid crystal display device can be provided wherein, when used with illumination extinguished in order to save power in well-lit locations, display quality is not lost and, when lit, high contrast is obtained with lower power consumption by using an LED or electric light bulb or the like.

[0037] It should be noted that the light source em-

ployed in the illumination device of the present example is not necessarily restricted to a point light source as described above. For example, as shown in Fig. 11, as light source, a short fluorescent tube 231 could be arranged along one optical input side end face of light-guide plate 11. In this connection "short fluorescent tube" means shorter than the length of the optical input side end face of the light-guide plate. The optical conversion efficiency of this fluorescent tube is about 10 ~ 20 lm/W, which is higher than the efficiency of an LED, which is about 5 lm/W and, since it is short, it can be lit with low power.

[0038] Also, the projections (projecting shapes) constituting the optical extraction structures capable of being applied in the present example are not necessarily restricted to those described above. The deformed pillar-shaped projections for example shown in Fig. 12A, 12B and Fig. 13 could be formed as a replacement for these. In the case of Fig. 12A, elliptical pillar-shaped projections 232 are arranged in two-dimensional fashion on light-guide plate 11; for a fluorescent tube 233 employed as a linear light source, optical output efficiency can be raised by arranging the direction of the major axis of the ellipse perpendicular to the light-guide direction (line joining the light source and the shortest distance of the projection). Also in the case of Fig. 12B, in which elliptical pillar-shaped projections 232 are arranged two-dimensionally on light-guide plate 11, optical output efficiency can likewise be raised by, for an LED employed as point light source, arranging the major axial direction of the ellipse perpendicular to the light-guide direction (line joining the light source and the shortest distance of the projection). Also, in the construction shown in Fig. 13, rounded-triangle pillar-shaped projections 233 are likewise arranged in two-dimensional fashion on the light-guide plate. In this case, depending on the number and direction of the light sources, it is desirable to arrange arcs of the projections which have largest radius perpendicular to the light-guide direction, as optical output efficiency can thereby be raised.

(first embodiment)

[0039] A first embodiment, which forms part of the present invention, is described with reference to the drawings. In Fig. 14A, a light source 2 is arranged at the end face of light-guide plate 11. As shown in Fig. 14B, light-guide plate 11 is provided with convex shapes 11A on one face of the transparent plate; the surfaces of convex shapes 11A are constituted by faces making an angle of less than about 30° with respect to the plane parallel to light-guide plate 11. Light-guide plate 11 is formed of transparent material of refractive index at least 1.4; if for example the refractive index is 1.4, the critical angle is 45°, and all the light rays input from end face 16 can be optically guided through light-guide plate 11. Specifically, as shown by light ray 19a or light ray 19b, the optical flux from light source 2, when input from end face 16, has a vector of less than about 45° with respect to the plane parallel to light-guide plate 11 and so undergoes repeated total reflection within light-guide plate 11. When in due course these reach convex shapes 11A, light rays that have been reflected at the faces of convex shapes 11A make a fairly large angle, greater than about 45°, with the plane parallel to light-guide plate 11 and can therefore be output from light-guide plate 11. A large amount of light is therefore output from the back face of the illuminating device and illuminated body 6 can be effectively illuminated.

[0040] As shown in Fig. 15, the faces of convex shapes 11A are constituted by faces of angle less than about 30° with respect to the plane parallel to light-guide plate 11. Since most of the components of the rays travelling through light-guide plate 11 are of angle less than 20° with respect to the plane parallel to light-guide plate 11, most of the rays being guided through light-guide plate 11 arrive at the faces of convex shapes 11A at more than the critical angle, so the reflected light can be output from another face of light-guide plate 11.

[0041] Fig. 16A shows an example in which the convex shape is a conical face (convex shape 11Aa); Fig. 16B shows an example in which it is a pyramidal shape (convex shape 11Ab); Fig. 16C shows an example in which it is a spherical surface (convex shape 11Ac); and Fig. 16D shows an example in which it is an irregularly shaped face (convex shape 11Ad). As described above, the shape can be freely chosen so long as the faces have an angle of under about 30° with respect to the plane parallel to light-guide plate 11 but conical faces as shown in Fig. 16A or a shape based on this are advantageous since the angle of the surface can be fixed and directionality of the surface direction is eliminated.

[0042] Fig. 17 shows an example in which the convex shapes are conical surfaces of apex angle about 130°. When a ray 91a parallel to light-guide plate 11 is reflected at the conical face, it makes an angle of 40° with respect to the normal of light-guide plate 11 and is output. Ray 91b making an angle of 20° makes an angle of 45° with the conical face and so is reflected; the reflected ray then makes an angle of 20° with the normal of light-guide plate 11 and so can be output. Ray 91c of angle more than 20° can be output from the conical face, but such components represent only a small proportion of the whole, so, by choosing an apex angle of about 130°, effective utilisation as illumination is possible.

[0043] For the transparent material forming light-guide plate 11, transparent resin such as acrylic resin, polycarbonate resin, or amorphous polyolefin resin, inorganic transparent material such as glass or a composite of these can be employed and these could be formed by a method such as joining a film or resin layer to an injection moulding, heat setting resin, photosetting resin, etching, or transparent resin or a flat glass plate. As light source 2, a fluorescent tube, electric light bulb, or light-emitting diode (LED) etc. could be employed. Flu-

orescent tubes have the advantages that high illuminance can be expected at low power and white light can easily be obtained. LEDs have a semi-permanent life and the circuitry is simple since they can be driven at low voltage and they have a high degree of safety in regard to catching fire or causing electric shock etc. Regarding colour, apart from red, green and blue, they have recently become available in mixed colours and/or white, so, depending on the application, they can be widely used. Electric light bulbs have the drawback of short life but they are cheap and have the possibility of being easily replaced.

[0044] These convex shapes 11A can be provided in any desired area ratio with respect to the area of the illumination unit.

[0045] However, although increasing the area ratio of convex shapes 11A enables the efficiency of illumination to be raised, since the ratio of perpendicularly transmitted rays is decreased, it lowers recognisability. In fact, setting an area ratio of above 50% is impracticable and setting an area ratio of about 10% is suitable for part-time illumination under dark conditions. Also, in the case where density is varied in order to achieve uniformity of illuminance as described above, if the ratio is about 10%, the area ratio of perpendicular transmission regions will lie in a range of about 80 ~ 90% so unevenness of recognisability depending on position is not experienced.

[0046] Regarding the size of convex shapes 11A, since the wavelength of visible light is from about 380 nm to 700 nm, the size should be at least about 5 μm if effects due to diffraction are not to occur and also should desirably be below about 300 μm in order that convex shapes 11 should not be noticeable to the naked eye. In addition to the above, from the point of view of convenience in manufacture, the size of convex shapes 11 is preferably more than about 10 μm and less than 100 μm.

[0047] By means of the above construction, part-time illumination can be achieved in which with the present illumination device arranged at the front face of an illuminated body 6, illuminated body 6 can be observed with illumination extinguished when the external light is sufficiently bright and illuminated body 6 can be observed with illumination turned on under dark conditions when the external light is insufficient. Examples of such an illuminated body 6 to which an illumination device as above can be applied include printed material such as printed paper or liquid crystal displays etc. The modified example shown in Fig. 18 is an example in which convex shapes as described above (the case where these are conical shapes is shown in Fig. 18) are distributed sparsely in the vicinity of light sources 2 but more densely as the distance from point light sources 2 increases. The optical flux density in light-guide plate 11 is high in the neighbourhood of light sources 2, but the optical flux density falls with distance going away from light sources 2 due to diffusion of the rays by convex shapes 11A, so convex shapes 11A are arranged more densely in continuous manner. Uniform illumination can thereby be achieved.

[0048] In the further modification shown in Fig. 19, reflecting member 4 is provided on faces, of the end faces of light-guide plate 11, other than the face where light sources 2 are arranged. This performs the action of returning once more into light-guide plate 11 rays that have been guided through light-guide plate 11 and have reached the end face.

[0049] Efficiency can thereby be improved. As reflecting member 4, a sheet or plate etc. having a white colour and/or a metallic lustre face is employed.

[0050] The modified example shown in Fig. 20 is an example in which a reflecting member 5 is arranged so as to cover end face 16 of light-guide plate 11 and light source 2. Rays from light source 2 can be directed effectively into end face 16, thereby contributing to improving illuminance and improving efficiency.

[0051] The modification shown in Fig. 21 is an example in which an optical absorbing member 6A is arranged at the periphery outside the range of illumination of light-guide plate 11. It would be possible to use for example double-sided tape or adhesive etc. at the junction of the reflecting member and light-guide plate as described above, but diffuse reflection due to micro particles or gas bubbles etc. within the adhesive layer might then allow rays other than the desired rays to escape from the light-guide plate. Optical absorbing members 6A have the function of absorbing such rays outside the range of illumination and making the illumination uniform.

[0052] In the modification shown in Fig. 22, a transparent plate or transparent sheet 7 is arranged on the observer side of light-guide plate 11. Light-guide plate 11 and the transparent plate or transparent sheet are not stuck together and an air layer is present, so if there is even slight damage to the surface of light-guide plate 11, light rays guided through its interior are reflected thereat and the damage can be recognised as a bright point or bright line from the surface. Not only is this unattractive in transparent type illumination but it also severely lowers recognisability due to loss of contrast etc. However, due to the provision of an air layer between the transparent plate or transparent sheet 7 and light-guide plate 11, there is no possibility of optical flux from light-guide 2 entering, so even if damage occurs thereto, it cannot result in the appearance of bright points or bright lines. Also in this case, since the relative area of any damage is slight, it can have very little effect on recognisability in regard to illuminated object 6. Since this light-guide plate 11 is employed as illumination arranged at the front, the presence of such a transparent plate or transparent sheet 7 is indispensable. As the transparent plate or transparent sheet 7, transparent resin such as acrylic resin, polycarbonate resin or amorphous polyolefin resin, or inorganic transparent material such as glass may be employed. Of course, similar to the discussion

of Fig. 5 above, optical diffusion members may be arranged as the point form optical extraction structures.

(second emboiment)

[0053] A second embodiment, which also forms part of the present invention, is described with reference to the drawings. In Fig. 23A, a light source 2 is arranged at the end face of light-guide plate 11. As shown in Fig. 23B, light-guide plate 11 is provided with concave shapes 11B on one face of the transparent plate, the faces of concave shapes 11B in all cases being constituted of surfaces making an angle of less than about 30° with respect to the plane parallel to light-guide plate 11. Light-guide plate 11 is formed of transparent material of refractive index of about 1.4 or more; if for example the refractive index is 1.4, the critical angle is 45°, so rays input from end face 16 can all be guided through light-guide plate 11. Specifically, when optical flux from light source 2 is input from end face 16 as shown by ray 19a or ray 19b, it has a vector of less than about 45° with respect to the plane parallel to light-guide plate 11 and so undergoes repeated reflection within light-guide plate 11. When in due course it reaches a concave shape 11B, a ray reflected at the faces of concave shape 11B will have a much larger angle exceeding about 45° with respect to the plane parallel to the light-guide plate 11 and can therefore be output from light-guide plate 11. Considerable optical output is therefore obtained from the back face of the illumination device and illuminated object 6 can be effectively illuminated.

[0054] As shown in Fig. 24, the faces of concave shapes 11B are constituted by faces having an angle of less than about 30° with respect to the plane parallel to light-guide plate 11. Since most of the components of the rays travelling through light-guide plate 11 have angles under about 20° with respect to the plane parallel to light-guide plate 11, most of the rays guided through light-guide plate 11 reach the surfaces of concave shapes 11B at above the critical angle, and so this reflected light can be output from another face of light-guide plate 11.

[0055] Fig. 25A shows an example in which the concave shapes are conical surfaces (concave shapes 11Ba); Fig. 25B shows an example in which they are pyramidal surfaces (concave shapes 11Bb); Fig. 25C shows an example in which they are spherical surfaces (concave shapes 11Bc); and Fig. 25D shows an example in which they are irregular-shaped surfaces (concave shapes 11Bd). So long as the angle which these faces make is below about 30° with respect to the plane parallel to light-guide plate 11 as above their shape can be freely selected but a conical surface as shown in Fig. 25A or surface of a shape based on this is advantageous since the angle can be fixed and directionality is eliminated.

[0056] Fig. 26 shows an example in which the concave shape is a conical surface of apex angle 130°. When a ray 191a parallel to light-guide plate 11 is reflected at the conical surface, it intersects the normal of light-guide plate 11 at 40° and so is output. Ray 191b making an angle of 20° intersects the conical face at 45° and so is reflected; this reflected light intersects the normal of light-guide plate 11 at 20° and so can be output. Ray 191c of angle exceeding 20° is output from the conical surface, but since such components represent only a small proportion of the whole, effective utilisation as illumination can be achieved by the choice of an apex angle of about 130°.

[0057] Details concerning the density and size of the concave shapes are in accordance with the description given for the case of the convex shapes above, without change. Provision of concave shapes on the light-guide plate in this way has the characteristic feature that, in comparison with convex shapes as described above, these shapes do not affect the thickness.

[0058] They are therefore suitable for constructing a notice board device having, as a whole, an illumination function in which a notice is used as the illuminated object, enabling a notice board device of extremely small thickness to be provided.

(Sixth embodiment)

[0059] Fig. 27 shows an example in which a liquid crystal display panel is employed for the illuminated body. Light-guide plate 11 is arranged at the front face of liquid crystal display panel 2001. A reflective type liquid crystal display device is constituted by arranging a reflecting plate 2002 at the back face of liquid crystal display panel 2001. Light-guide plate 11 has the function of directing rays of light towards liquid crystal display panel 2001 and of transmitting practically all of the rays reflected by reflecting plate 2002 without dispersion. This is effective when, if there is sufficient external light, it is used with light source 2 extinguished, as, in this case, light-guide plate 11 functions simply as a transparent plate and so does not lower recognisability and has no effect on display quality. Also, when it is turned on for use in dark locations where external light is insufficient, light-guide plate 11 illuminates liquid crystal display panel 2001 and the light reflected by reflecting plate 2002 is transmitted straight through with light-guide plate 11 functioning simply as a transparent plate in the same way as described above when extinguished, so this is effective in maintaining high recognisability.

[0060] Also, whereas, in the case of a transparent type liquid crystal display device in which the illumination device was arranged at the back face of the liquid crystal display panel, the bright/dark contrast was generated by the passage of rays from the illumination device once only through the liquid crystal display panel, with the present reflective type liquid crystal display device, in which the illumination device is arranged at the front face of the liquid crystal display panel, since rays of light from the illumination device pass through one

more time by being reflected by the reflecting plate after they have first passed through the liquid crystal display panel, higher contrast is obtained, which is effective in achieving higher recognisability.

[0061] Fig. 28 shows an example in which a liquid crystal display device according to the present invention is employed in an electronic device such as a mobile telephone. The display section of mobile telephone 4000 has a display 2000 as described above. In particular this is beneficial in achieving power saving in portable electronic devices.

[0062] As described above, small-thickness surface illumination can be provided suited for example to notice boards or liquid crystal displays that make use of external light. Also, a liquid crystal display device can be provided wherein, in applications such as portable electronic computer terminals, there is no loss of display quality even when used with illumination extinguished for power saving purposes in well lit locations and which is of high contrast when the illumination is turned on, with lower power consumption using a fluorescent tube, LEDs or electric light bulbs etc.

[0063] It should be noted that, with the illumination device of the present invention exemplified by the embodiments and modifications described above, various applications are possible. These are indicated by way of example in the form of a summary:

- ■ Illumination devices of portable devices such as portable telephones, small-size information devices, or watches.

- ■ Illumination devices for furniture such as ornamental shelf illumination, triple mirror lights, or the glass parts of tables.

- ■ Illumination devices for night illumination of large outdoor clocks, public maps, or timetable display boards at for example bus stops etc.

- ■ Illumination devices of for example sunroofs or covers for automobiles.

- Illumination devices for medical equipment such as mirror lights in dentistry
- Illumination devices used in illumination of compact reference books, illumination for in-flight reading material, or outdoor map illumination
- Illumination devices used for show case illumination, or for illumination of displays or art gallery exhibits
- Illumination devices used for louver illumination, photo frame illumination, or for small domestic items such as picture frame illumination
- Illumination devices for buildings such as illumination for windows, shower rooms, night illumination of entrances, indoor wall lighting, or illumination of frames set into walls
- Illumination devices for for example product illumination of automatic vending machines, illumination of the water in swimming pools, and illumination of outdoor company signboards etc.

[0064] There are a very wide range of industrial applications such as the above.

[0065] Of these, an example of an illumination device employed in for example outdoor map illumination is shown in Fig. 29A - Fig. 29C. This device has excellent portability, being of a compact size such as could be held in the palm of the hand (for example a size about that of a postcard). In this illumination device, transparent protective sheets 236 are respectively stuck on to the upper and lower faces of a light-guide plate 235 and reflective sheets 237 are respectively stuck on to three side faces. The functions of light-guide plate 235, protective sheets 236 and reflective sheets 237 are the same as or equivalent to those already described. A rectangular box-shaped case 236 is mounted on the remaining optical input side face portion of light-guide plate 235 so as to cover part of it. Within this case there are accommodated a battery 239 constituting a power source, a lighting circuit (inverter) 240, a fluorescent tube 241 constituting a linear light source, and a switch 242 etc. Fluorescent tube 241 is covered by a reflector 242. Lighting circuit 240 can thereby light fluorescent tube 241 with power from battery 239 when necessary so that the actions and effects described above can be obtained. A handy-type illumination device having a convenient high quality illumination function whereby a map can be viewed outdoors can thereby be provided.

Claims

1. An illumination device arranged at the front face of an illuminated object, comprising:

    a light-guide plate (11) of transparent flat plate shape formed with point-form optical extraction structures (11A, 11B); and
    a light source (2) arranged facing an end face (16) of this light-guide plate, said light source being a point light source, **characterised in that**:

        said point-form optical extraction structures are formed at the face (17) opposite an optical output face (13) facing said illuminated object (6); and
        said point-form optical extraction structures have a constant slope of less than about 30 degrees with respect to said face (17) opposite the optical output face (13).

2. An illumination device according to claim 1, wherein concave elements are provided as said point-form

optical extraction structures and.said concave elements (11B) have an incline face of less than about 30°; and

wherein said concave elements (11B) are distributed relatively sparsely in the vicinity of said point light source (2) and progressively more densely going away from said point light source.

3. An illumination device according to claim 1, wherein said optical extraction structures are relatively sparsely distributed in the vicinity of said point light source and are progressively more densely distributed going away from said point light source.

4. An illumination device according to claim 1, wherein optical diffusion members are arranged as said point-form optical extraction structures at the face (17) opposite the optical output face (13) facing said illuminated object of said light-guide plate.

5. An illumination device according to any one of the preceding claims, wherein a light emitting diode (LED) is employed as said point light source.

6. An illumination device according to any one of claims 1 to 4, wherein an electric light bulb is employed as said point light source.

7. An illumination device according to any one of the preceding claims, wherein a sheet-form transparent member (7) is arranged facing the face (17) opposite the optical output face (13) facing said illuminated object of said light-guide plate.

8. An illumination device according to claim 1, wherein convex elements (11A) are provided as said point-form optical extraction structures.

9. An illumination device according to claim 8, wherein said convex elements are distributed relatively sparsely in the vicinity of said point light source and progressively more densely going away from said point light source.

Patentansprüche

1. Beleuchtungsvorrichtung, die an der Vorderseite eines beleuchteten Objekts angeordnet ist, umfassend:

eine Lichtführungsplatte (11) mit einer transparenten flachen Plattenform, die mit punktförmigen optischen Extraktionsstrukturen (11A, 11B) versehen ist; und
eine Lichtquelle (2), die einer Stirnfläche (16) dieser Lichtführungsptatte zugewandt angeordnet ist, wobei die Lichtquelle eine Punktlichtquelle ist; **dadurch gekennzeichnet, daß**

die punktförmigen optischen Extraktionsstrukturen auf der Fläche (17) gegenüberliegend einer optischen Austrittsfläche (13), die dem beleuchteten Objekt (6) zugewandt ist, ausgebildet sind; und

die punktförmigen optischen Extraktionsstrukturen eine konstante Neigung von weniger als etwa 30° bezüglich der der optischen Austrittsfläche (13) gegenüberliegenden Fläche (17) aufweisen.

2. Beleuchtungsvorrichtung nach Anspruch 1, bei der konkave Elemente als punktförmige optische Extraktionsstrukturen vorgesehen sind und die konkaven Elemente (11B) eine Neigungsfläche von weniger etwa 30° aufweisen; und wobei

die konkaven Elemente (11B) relativ spärlich in der Nähe der punktförmigen Lichtquelle (2) und mit zunehmender Entfernung von der punktförmigen Lichtquelle zunehmend dichter verteilt sind.

3. Beleuchtungsvorrichtung nach Anspruch 1, bei der die optischen Extraktionsstrukturen relativ spärlich in der Nähe der Punktlichtquelle und mit zunehmender Entfernung von der Punktlichtquelle zunehmend dichter verteilt sind.

4. Beleuchtungsvorrichtung nach Anspruch 1, bei der die optischen Diffusionselemente als punktförmige optische Extraktionsstrukturen an der Fläche (17) gegenüberliegend der optischen Austrittsfläche (13), die dem beleuchteten Objekt der Lichtführungsplatte zugewandt ist, angeordnet sind.

5. Beleuchtungsvorrichtung nach irgendeinem der vorangehenden Ansprüche, bei der eine lichtemittierende Diode (LED) als Punktlichtquelle verwendet wird.

6. Beleuchtungsvorrichtung nach irgendeinem der Ansprüche 1 bis 4, bei der eine elektrische Glühbirne als Punktlichtquelle verwendet wird.

7. Beleuchtungsvorrichtung nach irgendeinem der vorangehenden Ansprüche, bei der ein plattenförmiges transparentes Element (7) der Fläche (17) zugewandt angeordnet ist, welche der optischen Austrittsfläche (13) gegenüber liegt, die dem beleuchteten Objekt der Lichtführungsplatte zugewandt ist.

8. Beleuchtungsvorrichtung nach Anspruch 1, bei der konvexe Elemente (11A) als punktförmige optische Extraktionsstrukturen vorgesehen sind.

9. Beleuchtungsvorrichtung nach Anspruch 8, bei der

die konvexen Elemente relativ spärlich in der Nähe der Punktlichtquelle und mit zunehmender Entfernung von der Punktlichtquelle zunehmend dichter verteilt sind.

Revendications

1. Dispositif d'éclairage, disposé au niveau de la face frontale d'un objet éclairé, et comprenant :

   une plaque de guidage de lumière (11), sous la forme d'une plaque plate transparente formée avec des structures d'extraction optique en forme de points (11A, 11B) ; et
   une source de lumière (2), disposée en face d'une face d'extrémité (16) de cette plaque de guidage de lumière, ladite source de lumière étant une source de lumière ponctuelle, **caractérisé en ce que** :

      lesdites structures d'extraction optique en forme de points sont formées au niveau de la face (17) qui est à l'opposé d'une face de sortie optique (13), faisant face audit objet éclairé (6) ; et
      en ce que lesdites structures d'extraction optique en forme de points ont une pente constante, qui est inférieure à environ 30 degrés par rapport à ladite face (17), située à l'opposé de la face de sortie optique (13).

2. Dispositif d'éclairage selon la revendication 1, dans lequel il est prévu des éléments concaves, en tant que lesdites structures d'extraction optique en forme de points, et en ce que lesdits éléments concaves (11B) ont une face inclinée à moins d'environ 30° ; et
   dans lequel lesdits éléments concaves (11B) sont répartis de manière relativement clairsemée à proximité de ladite source de lumière ponctuelle (2) et, progressivement, de façon plus dense au fur et à mesure que leur distance augmente par rapport à ladite source de lumière ponctuelle.

3. Dispositif d'éclairage selon la revendication 1, dans lequel lesdites structures d'extraction optique sont réparties de manière relativement clairsemée à proximité de ladite source de lumière ponctuelle et sont réparties ensuite, progressivement, de façon plus dense au fur et à mesure que leur distance augmente par rapport à ladite source de lumière ponctuelle.

4. Dispositif d'éclairage selon la revendication 1, dans lequel des éléments de diffusion optique sont disposés, en tant que lesdites structures d'extraction optique en forme de points, au niveau de la face (17) qui est à l'opposé d'une face de sortie optique (13), faisant face audit objet éclairé de ladite plaque de guidage de lumière.

5. Dispositif d'éclairage selon l'une quelconque des revendications précédentes, dans lequel on utilise, en tant que ladite source de lumière ponctuelle, une diode lumineuse (LED).

6. Dispositif d'éclairage selon l'une quelconque des revendications 1 à 4, dans lequel on utilise, en tant que ladite source de lumière ponctuelle, une ampoule d'éclairage électrique.

7. Dispositif d'éclairage selon l'une quelconque des revendications précédentes, dans lequel un élément transparent en forme de feuille (7) est disposé en face de la face (17), qui est à l'opposé de la face de sortie optique (13), faisant face audit objet éclairé de ladite plaque de guidage de lumière.

8. Dispositif d'éclairage selon la revendication 1, dans lequel des éléments convexes (11A) sont prévus, en tant que lesdites structures d'extraction optique en forme de points.

9. Dispositif d'éclairage selon la revendication 8, dans lequel lesdits éléments convexes sont répartis de manière relativement clairsemée à proximité de ladite source de lumière ponctuelle et sont répartis ensuite, progressivement, de façon plus dense au fur et à mesure que leur distance augmente par rapport à ladite source de lumière ponctuelle.

FIG.1A

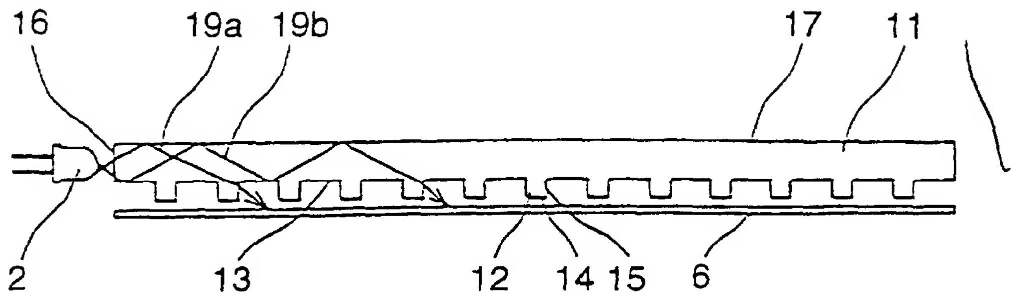

FIG.1B

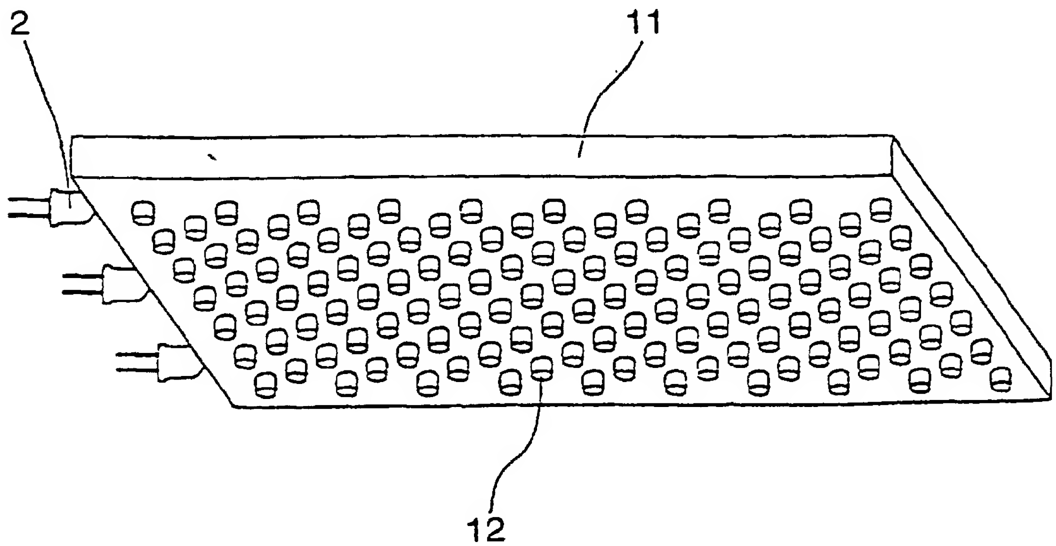

FIG.2A

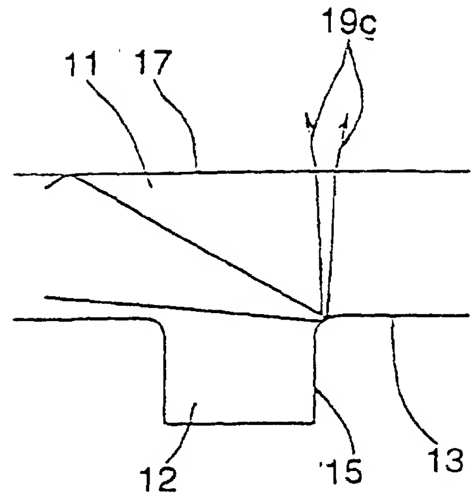

FIG.2B

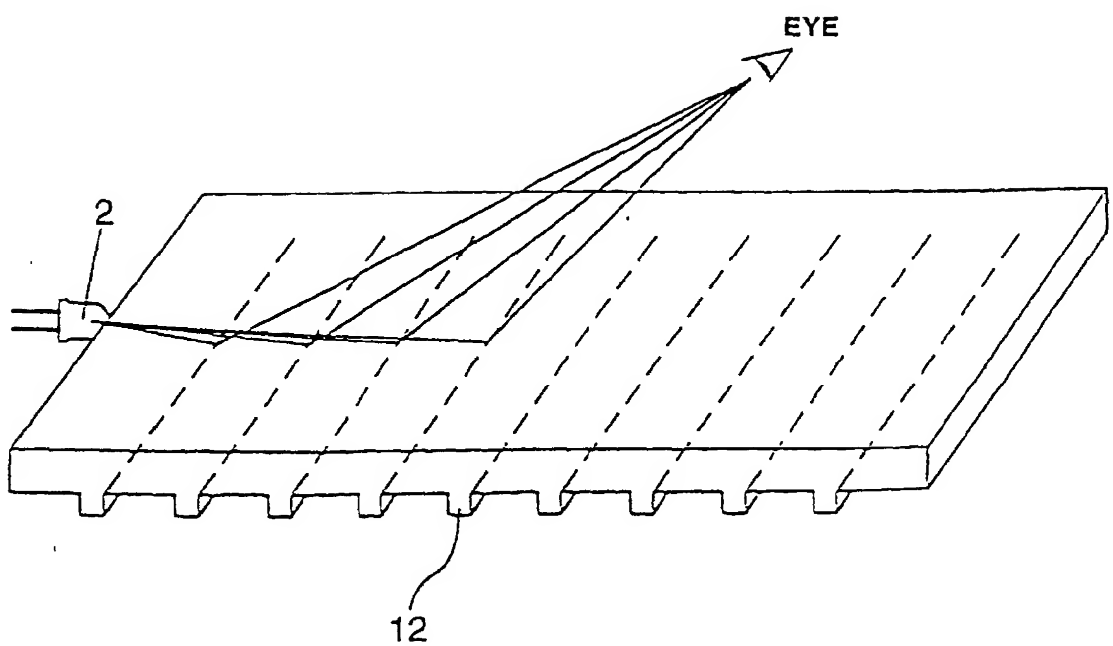

FIG.3

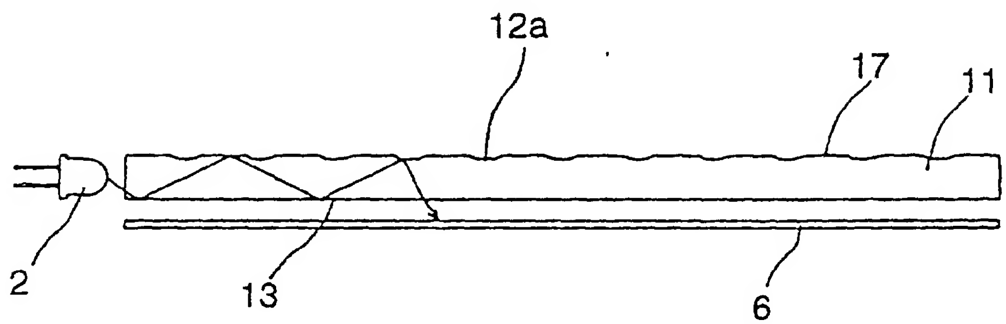

FIG.4

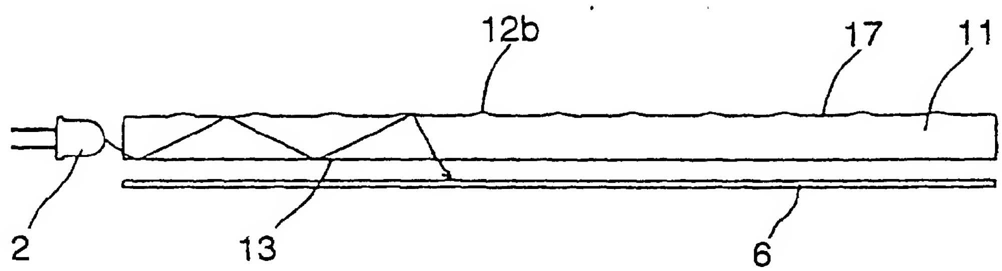

FIG.5

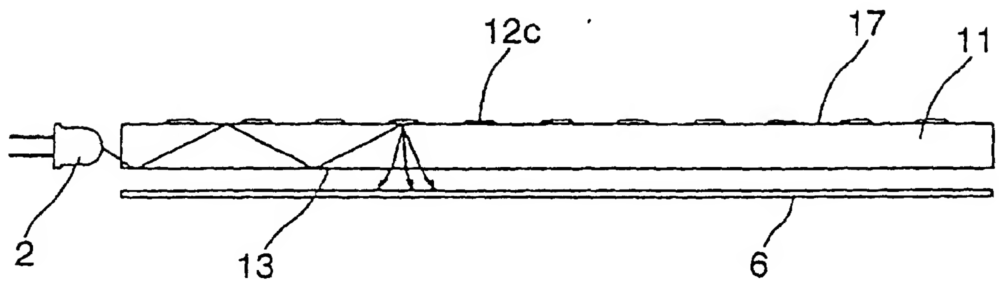

FIG.6

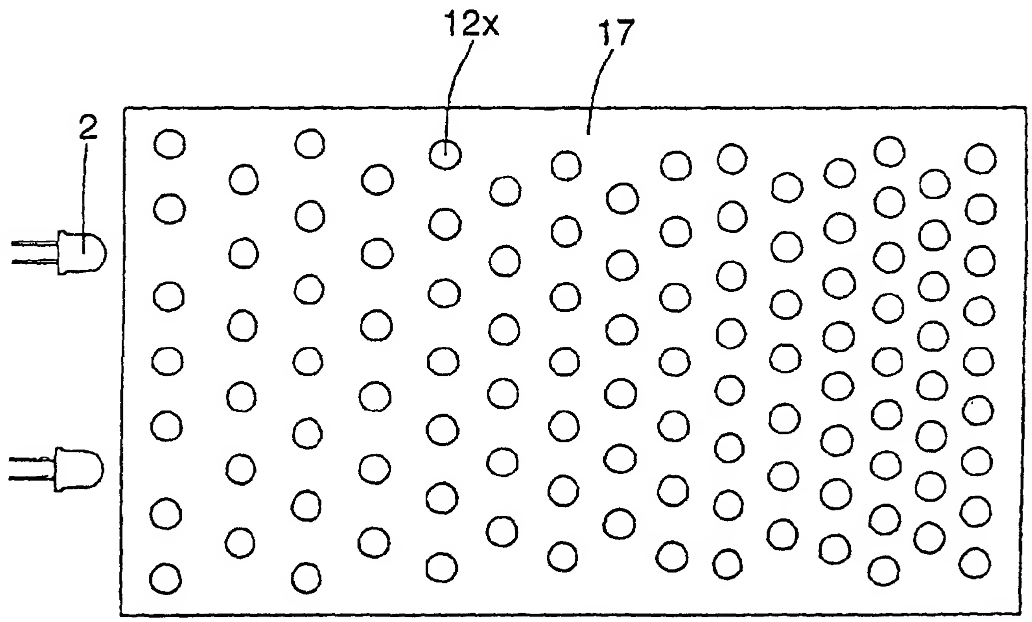

FIG.7

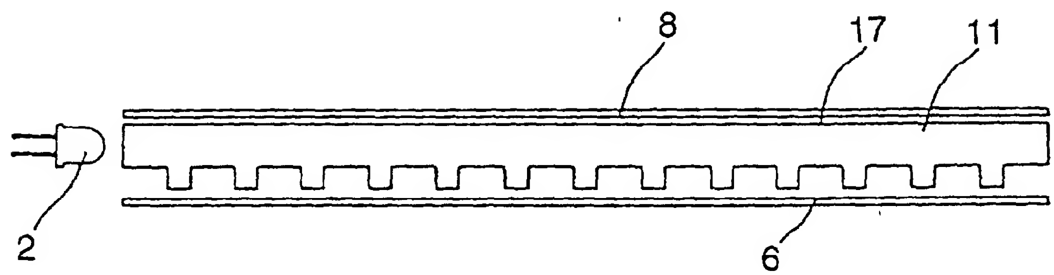

FIG.8

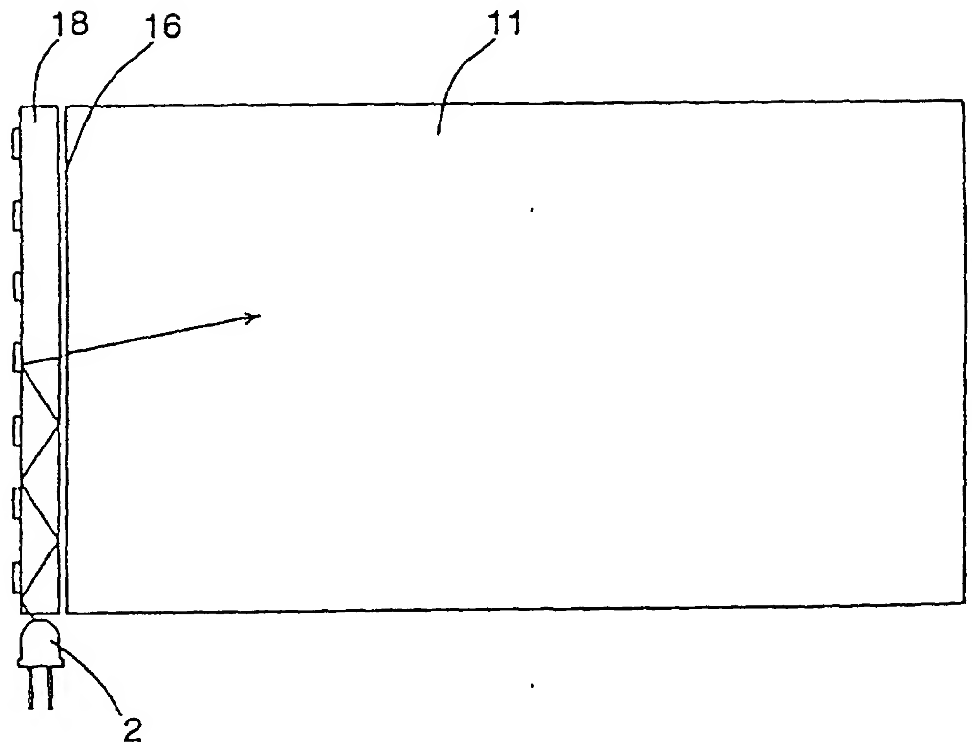

FIG.9A

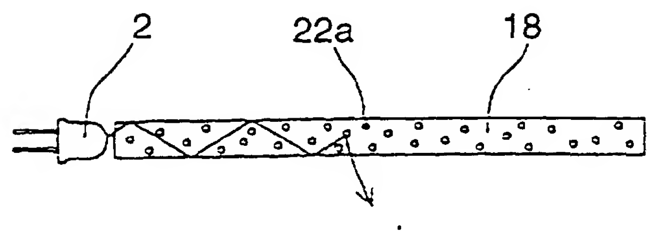

FIG.9B

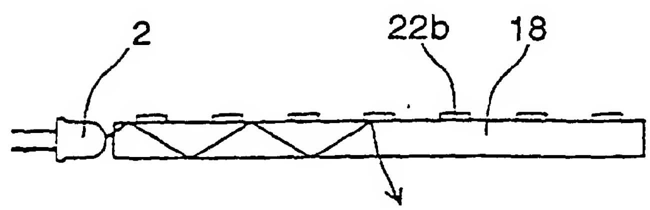

FIG.10

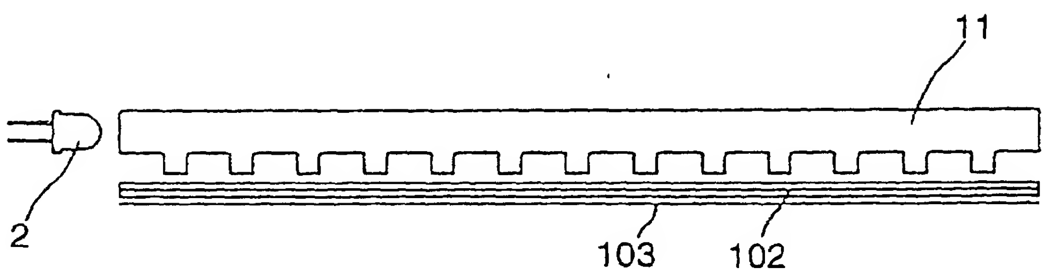

FIG.11

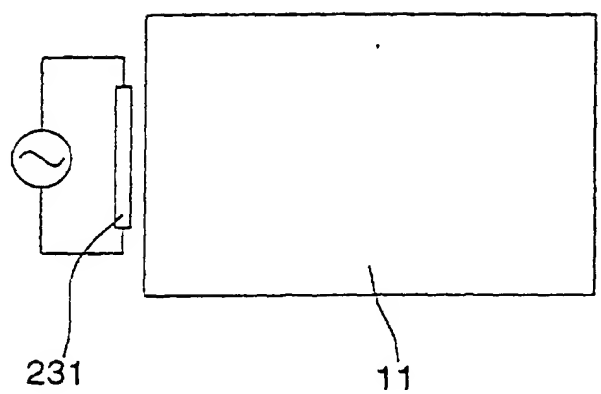

FIG.12A

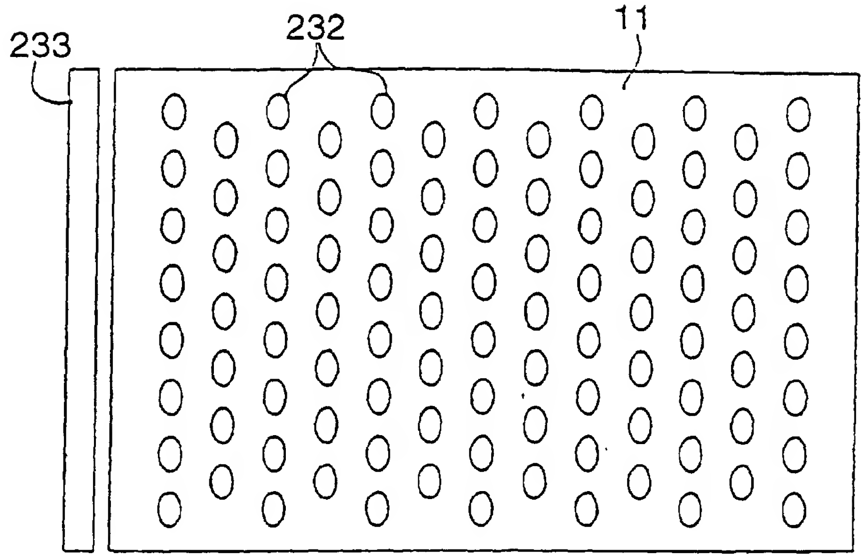

FIG.12B

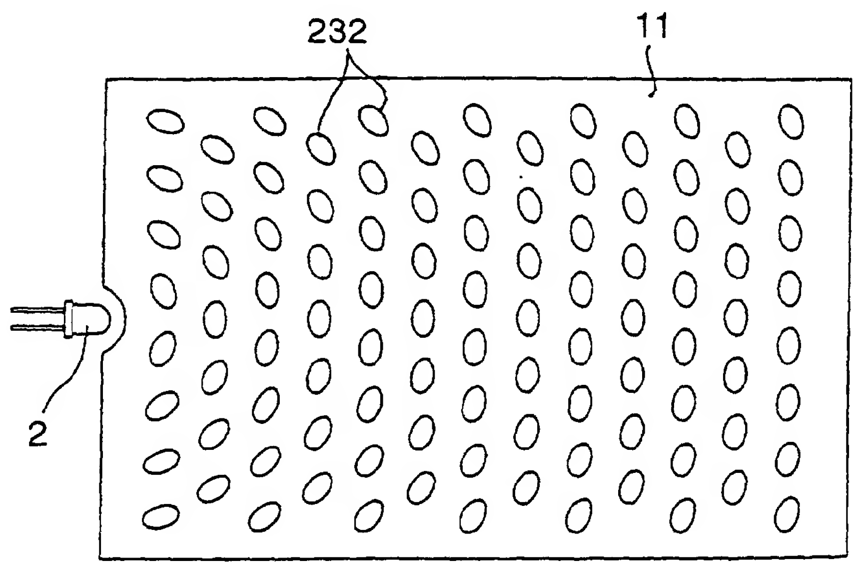

FIG.13

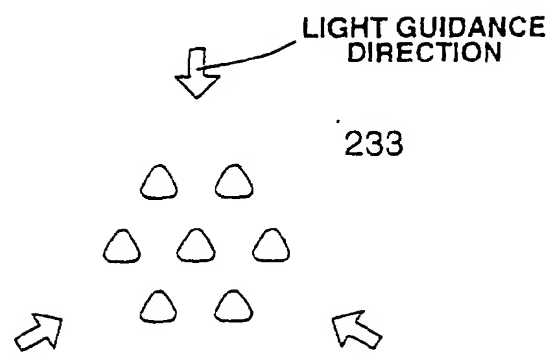

FIG.14A

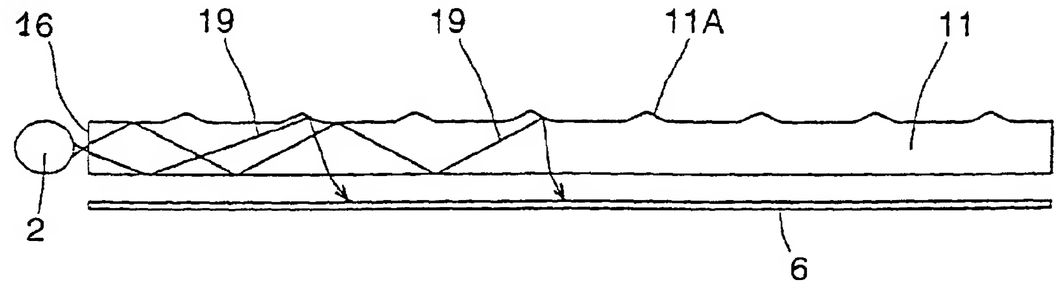

FIG.14B

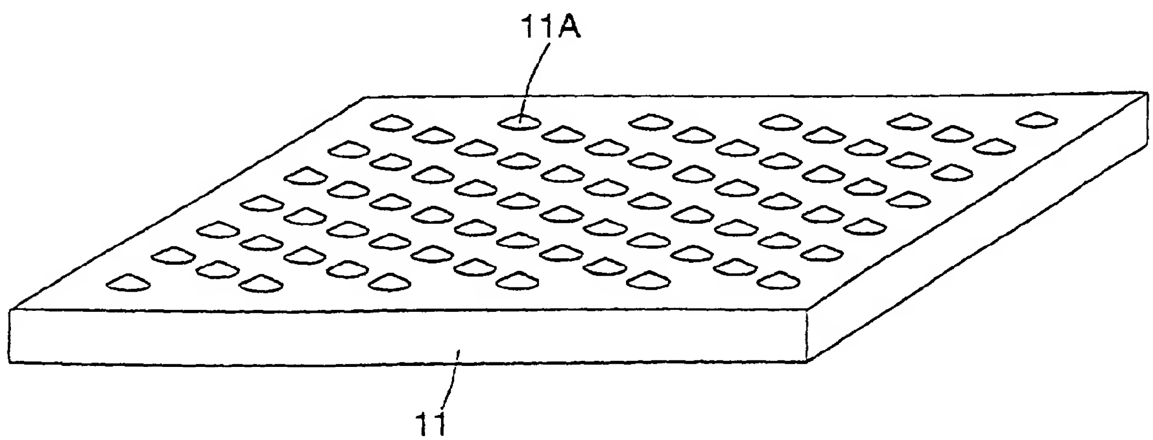

FIG.15

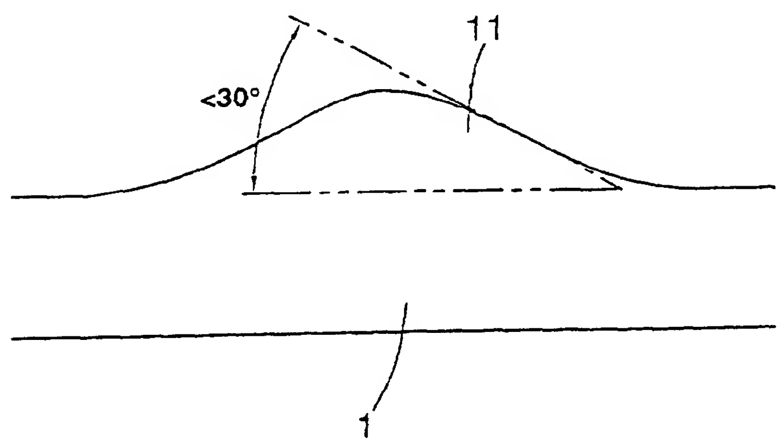

FIG.16A

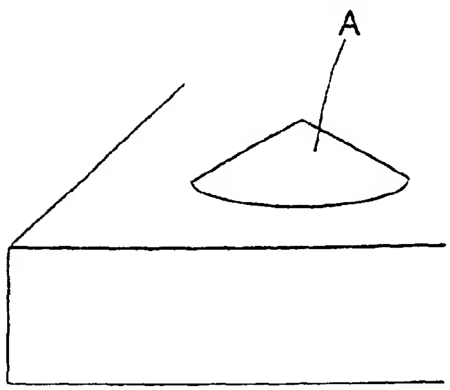

FIG.16B

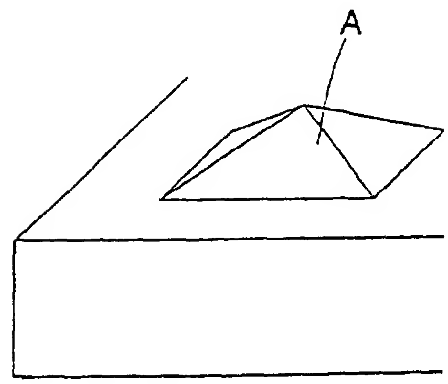

FIG.16C

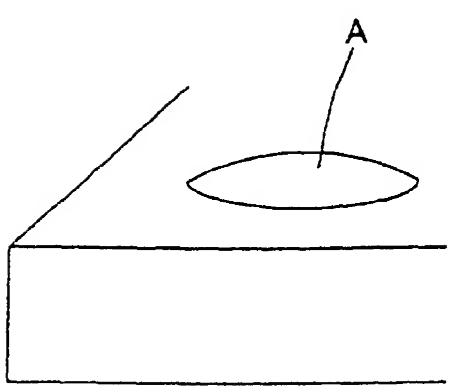

FIG.16D

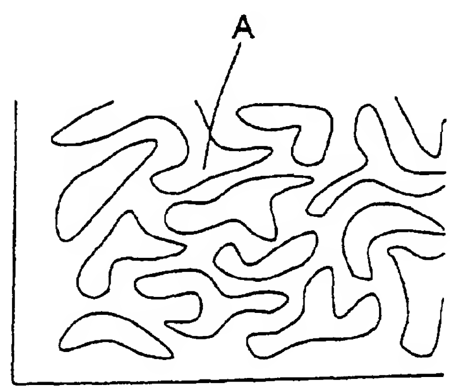

FIG.17

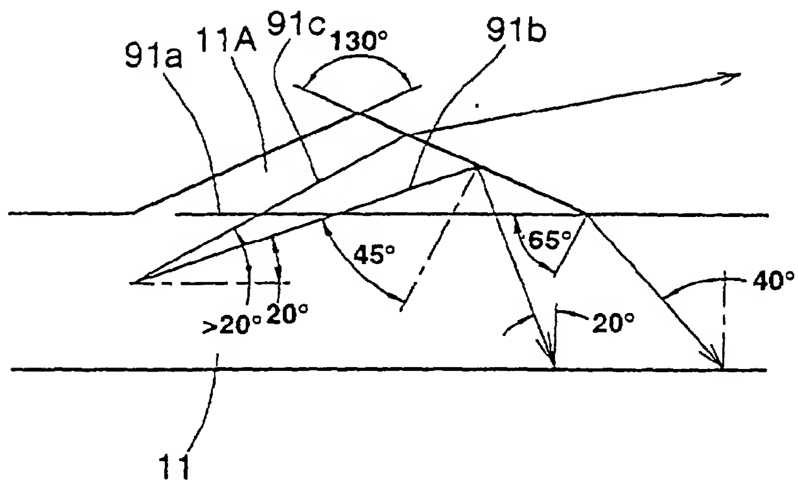

FIG.18

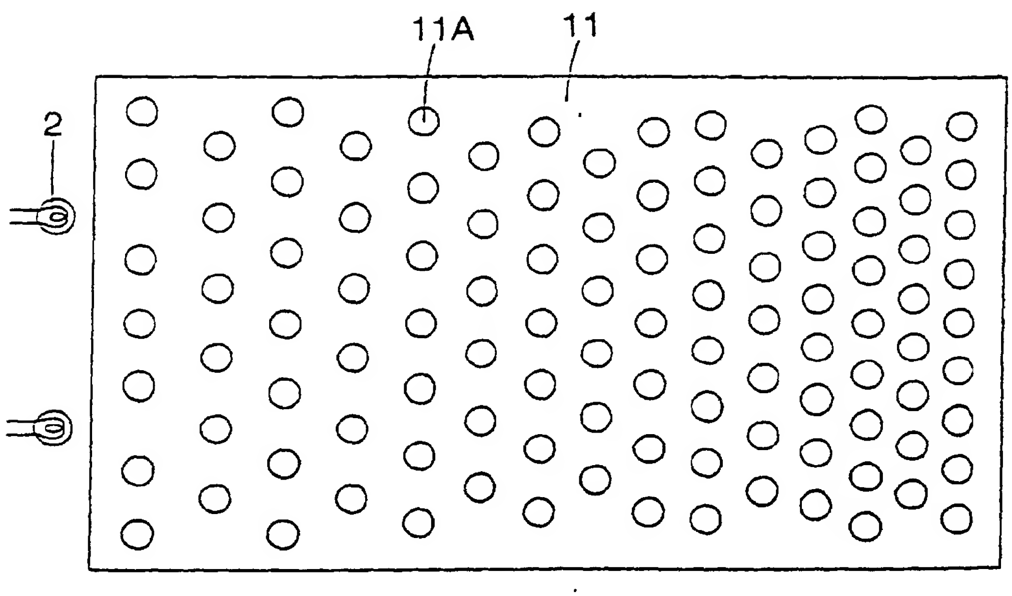

FIG.19

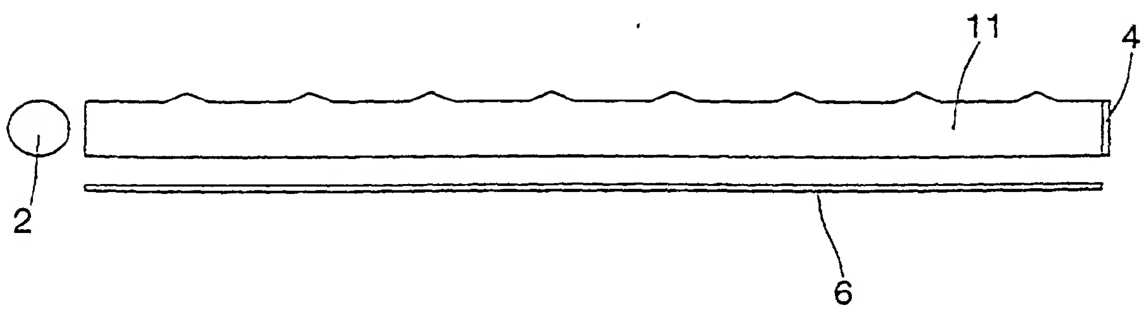

FIG.20

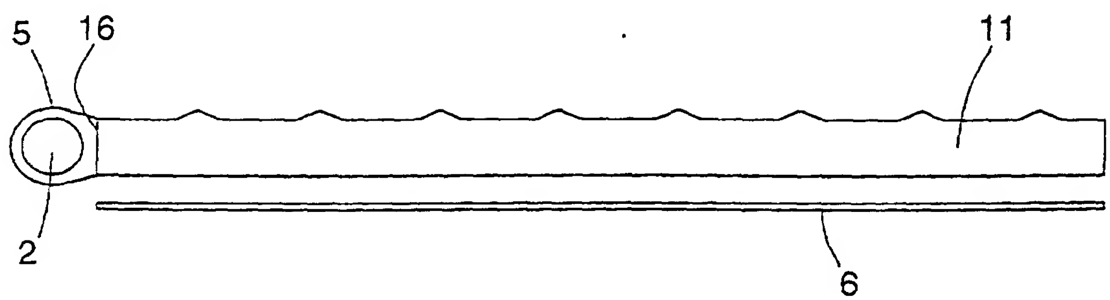

FIG.21

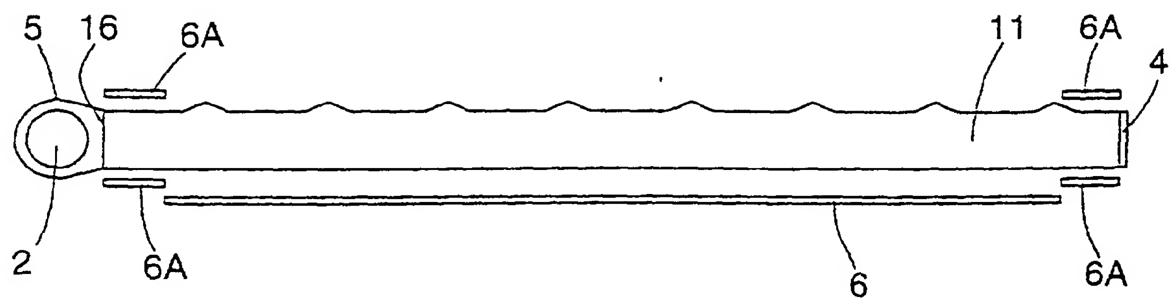

FIG.22

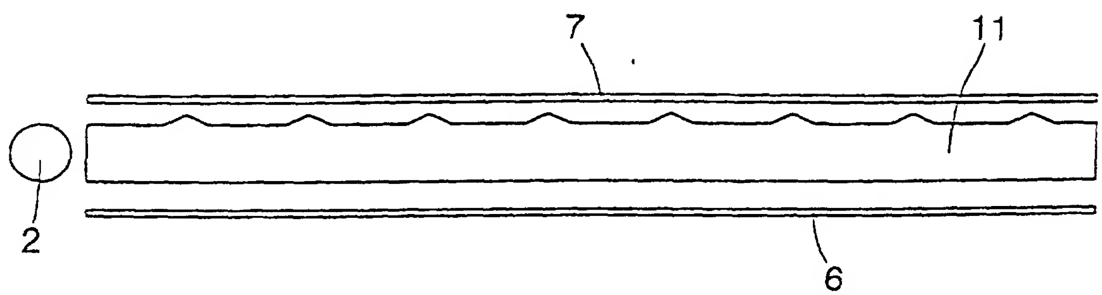

FIG.23A

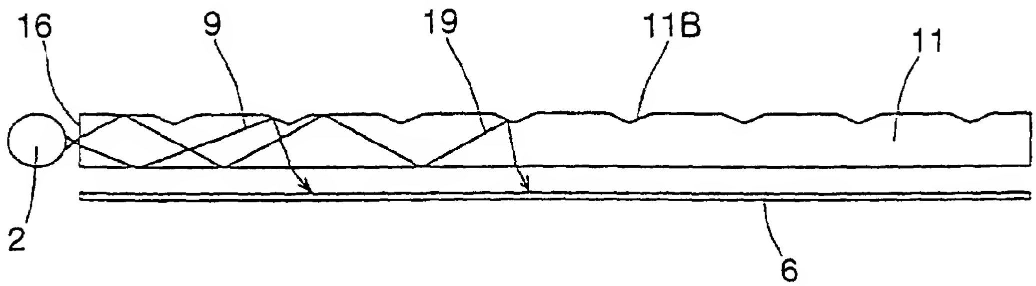

FIG.23B

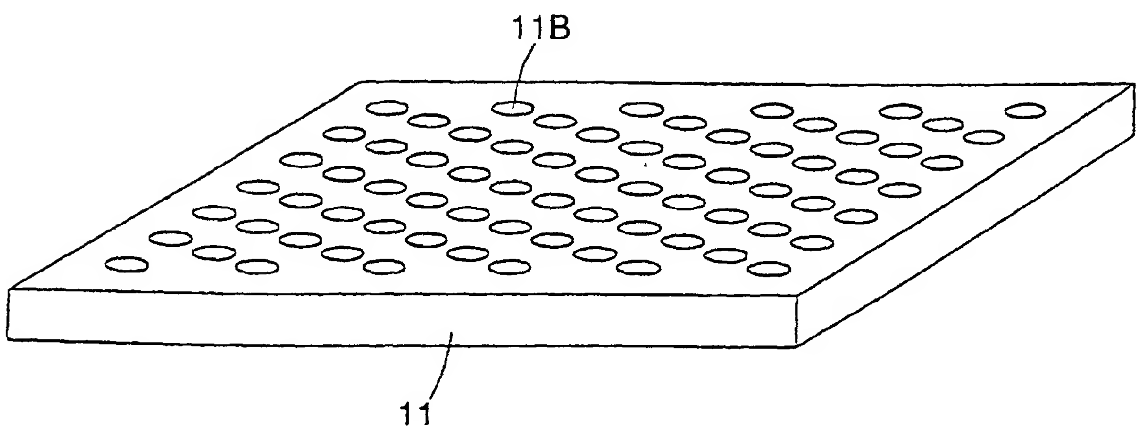

FIG.24

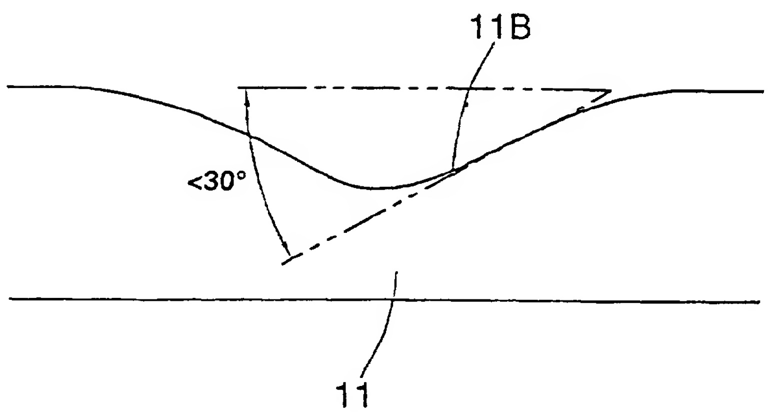

FIG.25A

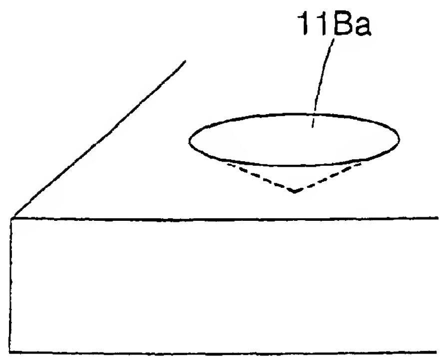

FIG.25B

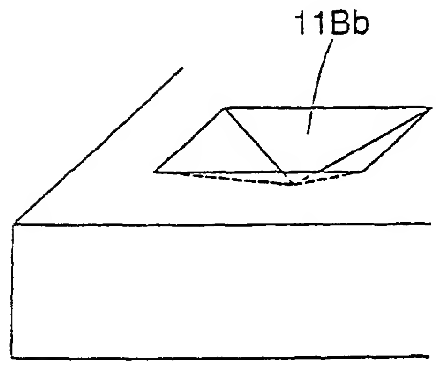

FIG.25C

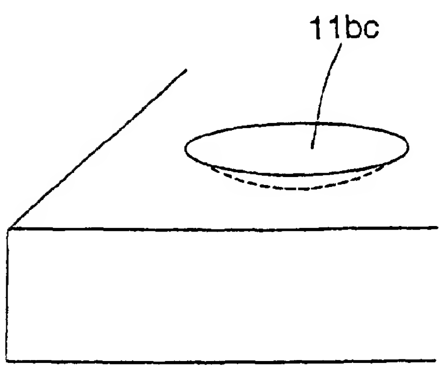

FIG.25D

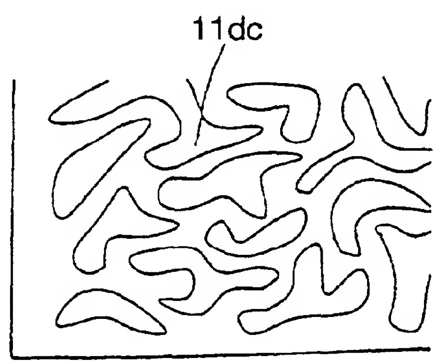

FIG.26

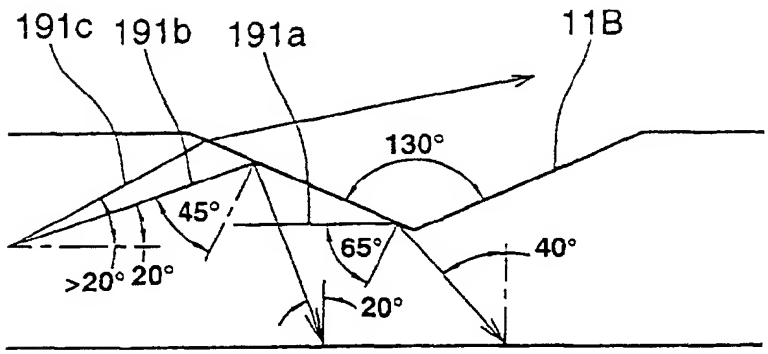

FIG.27

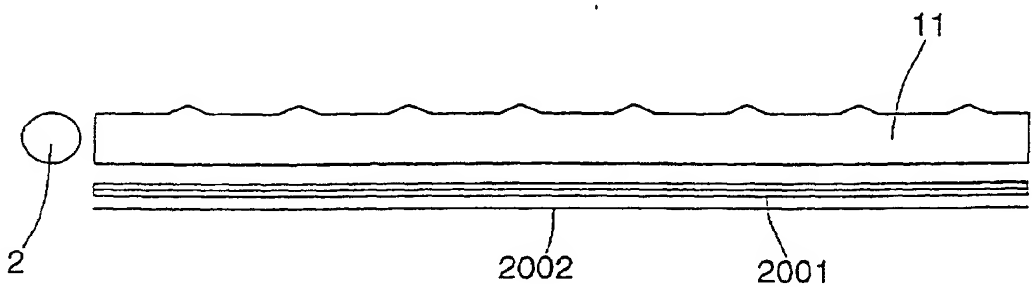

FIG.28

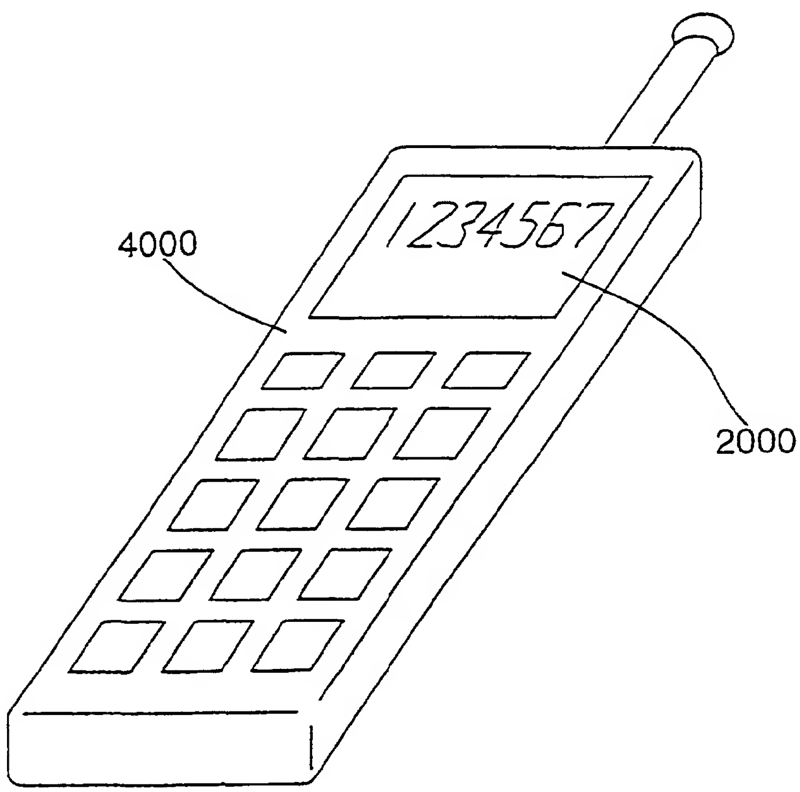

FIG.29A

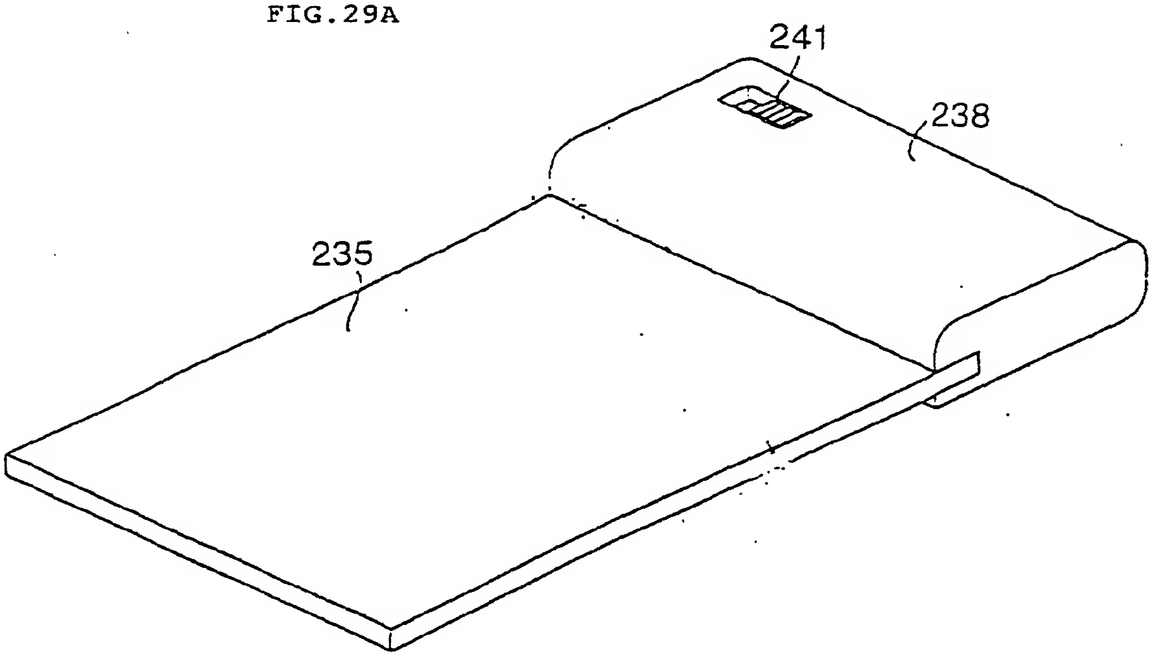

FIG. 29C

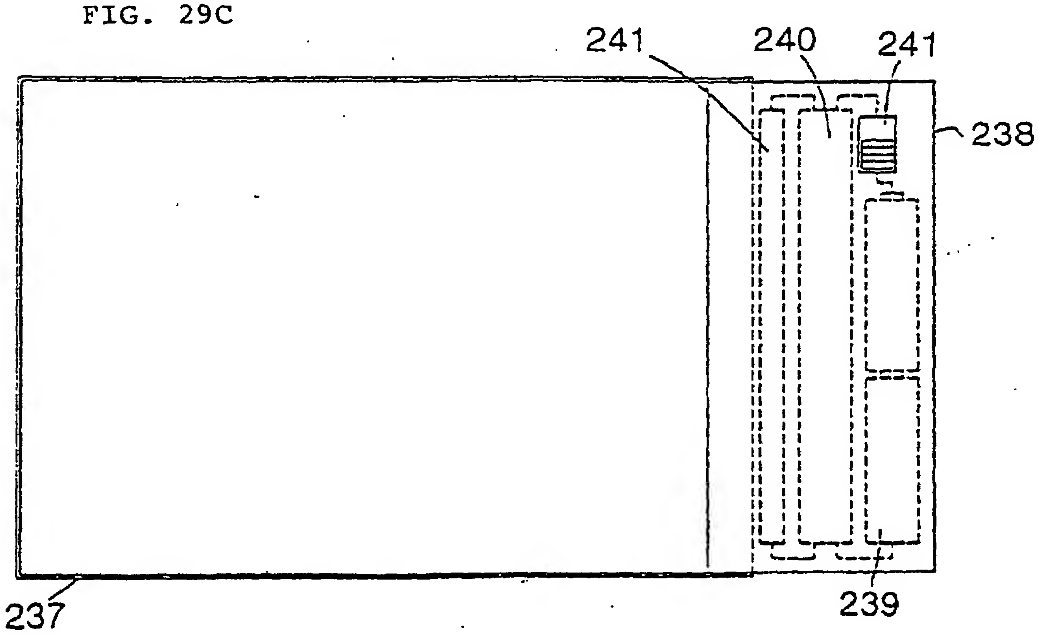

FIG. 29C